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TRANSPORT OF NUTRIENTS AND PHYTOPLANKTON INTO TWO GLACIAL PRAIRIE LAKES

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ABSTRACT

The objectives of this study were to describe and compare inflow rates, nutrient concentrations and phytoplankton taxa in two South Dakota prairie lakes of different trophy: Eutrophic Lake Cochrane (Deuel County) and hypertrophic Oak Lake (Brookings County).

Stream flows, total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrite-nitrate-N, iron, silica, manganese, calcium, sodium, conductivity and algal species composition and density were measured from Lake Cochrane on three dates in 1997. Sampling sites included a natural inflow below a sediment control dam, an artificial diversion pipe from Lake Oliver to Lake Cochrane, an artificial outflow from Lake Cochrane and a mid-basin site. Lake Oak was sampled on two dates in 1997 from major inflows from the west and north, spring seepage flowing into the lake on the west shore, and a mid-basin site.

Mean concentrations of TP in Lake Cochrane were highest in the inflow from the sediment control dam, intermediate in the inflow from Lake Oliver and lowest midbasin. TN concentrations were highest midbasin and in the inflow from Lake Oliver, and lowest in the inflow from the sediment control dam. Average P loading rates were 116.3 g/da from Lake Oliver and 8.2 g/da from the sediment dam. Outlet removal was estimated at 24.8 g/da. TN loading rates were 43.7 g/da from the sediment control dam and 2005.6 g/day from Lake Oliver. Outlet removal was estimated at 919.2 g/day. Populations of green algae and cryptophyte flagellates were highest in the in the inflow from the sediment control dam. Dinoflagellates and *Botryococcus* were highest midbasin. Chrysophyte flagellates and coccoid bluegreen algae were most abundant in the outlet.

In Oak Lake, mean concentrations of both TP and TKN were highest midbasin and lowest in the inflows. Average P loading rates were 25.5 g/da from the west inflow, 2.6 g/da from the west seepage area and 68.3 g/da from the north inflow. Average N loading rates were 94.0 g/da from the west inflow, 67.7 g/day from the west seepage and 715.3 g/day from the north inflow. Populations of most taxonomic groups of algae were greatest at the midbasin site.

Loading of P into Lake Cochrane may threaten the high water quality currently present in that lake. The Lake Oliver inflow is of particular concern. Oak lake may be generating much of its P internally. N-fixing bluegreen algae are

stimulated by high P levels and contribute to high TKN levels measured midlake. Restoration of higher water quality to Oak Lake may require sediment removal.

INTRODUCTION

Prairie lake water quality has been degraded by cultural eutrophication and formation of blooms of bluegreen algae (Cyanobacteria). Inflows of nutrients, particularly phosphorus (P) into lakes has been assumed to stimulate algal blooms (Thomas 1969) and removal of P from inflowing waters has resulted in dramatic improvement of water quality (Thomas, 1973, Edmondson 1991). Algae increases in prairie lakes have been associated with increases in both nitrogen (N) and P (Haertel 1976, Smith 1982, Buskerud and Haertel 1992). Iron (Fe) may also be limiting to many algae and may prevent N-fixation by bluegreens (Goldman and Horne 1983). Silicon (Si) is a major nutrient for diatoms and lack of Si may trigger a change from a more desirable diatom flora to a less desirable bluegreen flora (Schelske and Stoermer 1972). Manganese (Mn) can also sometimes limit algae (Lange 1971) and limits the rate of photosynthesis (Vymazal 1995). Calcium (Ca) influences algal nutrient uptake (Rigby *et al* 1980) and also may help precipitate P from the water column (Danen-Louwerse *et al* 1995). Sodium (Na) may benefit N metabolism in bluegreen algae (Ward and Wetzel 1975).

The purpose of this study was to compare concentrations of nutrients and phytoplankton, in inflows and midbasin waters of Lakes Oak and Cochrane located in eastern South Dakota. Loading rates were also calculated for P and N.

STUDY AREA AND METHODS

Oak Lake is hypertrophic (mean midbasin total P of 277 ug/l, mean Secchi depth of 0.2 m, and mean chlorophyll *a* of 86 ug/l), has a mean specific conductance of 472 uS/cm, a surface area of 1.6 km^2, a mean depth of 1.1 m, a maximum depth of 2 m, and drains a watershed of 16.8 km^2 (Troelstrup, unpublished data). Intermittent streams flow into Oak lake from the west, north and south. Above ground springs also contribute water to the west shore of Oak lake and to the west inflowing stream. Sampling stations in Oak Lake (Figure 1) were in the north inlet, west inlet, cattail littoral zone at the entrance of the west inlet, downstream from one of the major seepages and midbasin. The west inlet drains an area of 2.4 km^2 and the north inlet drains an area of 6.0 km^2.

Lake Cochrane is eutrophic (mean midbasin total P of 24 ug/l, mean Secchi depth of 1.3 m, and mean chlorophyll *a* of 10 ug/l), has a mean specific conductance of 2119 uS/cm, a surface area of 1.5 km^2, a mean depth of 3.9 m, a maximum depth of 7.9 m, and drains a natural watershed of 3.6 km^2. Intermittent streams enter Lake Cochrane from the south and west. The lake has no natural outflow. The south inlet to Cochrane was not flowing in 1997. The west inlet to Cochrane enters a constructed open water sediment retention pond before flowing through cattail-bulrush littoral zone. Beginning in 1993, an artificial diversion was constructed to allow water from Lake Oliver to enter Lake Cochrane, adding runoff from the Oliver watershed of 1.3 km^2 to Lake Cochrane. An artificial outlet from Cochrane had previously been constructed. Sampling stations in Lake Cochrane (Figure 2) were in the west inlet just below the sediment retention pond, in the artificial inlet from Lake Oliver just above or below the final culvert entering Lake Cochrane, in the central lake basin, and just below the artificial outlet culvert.

Water Chemistry

Oak Lake was sampled June 17 and July 14, 1997. The west littoral zone station was not sampled July 14. Replicate samples were collected from Lake Cochrane June 11, July 14 and August 26, 1997. After June 11, only current flow measurements were taken in the outlet. Two replicate samples of each variable were taken at each location. Samples for total P were frozen in polycarbonate bottles, and samples for Total Kjeldahl N (TKN), nitrite-nitrate N, and chlorophyll *a* were refrigerated prior to return to the laboratory. Nitrogen samples were processed the day after collection.

The following methods of the U. S. Environmental Protection Agency (1983) were used for laboratory analysis: TKN 351.3 (colorimetric), nitrite-nitrate N 300A (ion chromatography), total P 365.1 (persulfate digestion, colorimetric), and cations by atomic absorption, direct aspiration (Ca, 215.1, and Na 273.1). Total nitrogen was determined by summing TKN and nitrite-nitrate nitrogen. Nitrite N was assumed to be negligable at the pH levels measured (Mortimer 1941-1942). Chlorophyll samples were filtered and frozen the same day as collected. Chlorophyll *a* was measured colorimetrically following acetone extraction (APHA 1985).

Field measurements of temperature were made with a bucket thermometer. Electrical conductivity was measured with a LaMotte DA DS conductivity meter. pH was determined colorimetrically (Hach Chemical Corp., Loveland, CO, method 17-N). Turbidity was measured with a Hach 2100 P turbidometer. Water transparency was determined with the use of a 20 cm white and black Secchi disk. Field chemical measurements were performed for Fe (Hach IR-21) Mn (Hach Mn-PAN) and Si (Hach SI-7 or SI-5) to enable same day analysis.

Stream Discharge

Inlet and outlet stream flows were estimated from measurements of stream width, depth and current velocity (@60% of maximum depth) from several points within each channel (Carter and Dividian 1969). Oak Lake stream flows were measured on chemistry sampling dates (except for outlet and south inlet sites). Additional stream flow data were obtained from the Oak Lake Field Station Monitoring database (Troelstrup, unpublished data) to improve estimates of critical and actual loading to Oak Lake. These data were collected biweekly, during the ice-free season from 1996-1998. Lake Cochrane stream flows were measured only on chemistry sampling dates (1997). No other discharge data were collected for this basin.

Phytoplankton

Algal samples were preserved in Lugol's solution and counted, after settling, in a Sedgwick-Rafter Cell at both 100x and 300x, using a Whipple Disc. Two or more crosswise swipes were counted at low power for larger forms and one or more swipes at high power for all forms. All samples were counted until at least 100 units of the most abundant species were encountered (Lund et al. 1958). Eukaryotic algae were counted as cells. Large colonial bluegreen algae were counted by measuring the number of squares of the Whipple Disc grid covered by the colony. Values were then converted to cells by counting average numbers of cells per square and multiplying by the number of squares covered. Length of filamentous bluegreen algae was measured using the Whipple Disc and similarly converted to number of cells.

Algae were identified and counted as species whenever possible, but for simplicity, some taxa were analyzed as genera. *Nitzschia* and *Synedra* could not be reliably separated in a Sedgwick-Rafter cell and were counted by size categories. Identification of selected individuals on a regular microscope slide enabled determination of the more abundant forms. Infrequently encountered genera were added into higher taxonomic groups totals. Eukaryotic algae were identified according to keys in Smith (1950), Prescott (1962, 1978), Tiffany and Britton (1971), and Komarkova-Legnerova (1969). Most bluegreen algae were identified according to Drouet (1959), where the traditional genera *Microcystis* and *Aphanothece* are changed to *Anacystis* and *Coccochloris*, respectively. *Gleocapsa* and *Calothrix* were identified according to Rippka *et al* (1979).

Statistical Analysis

Means of measured concentrations of variables were compared between stations within lakes using one-way analysis of variance (PROC GLM, SAS Institute Inc. 1989).

RESULTS

Nutrient levels

In Oak Lake, turbidity, pH, total P and total N concentrations were much higher in the midbasin station than in any of the tributaries (Table 1). Because of the larger flow rate, most of the incoming N and P was entering the lake from the north inlet (Table 2). Far more N and P was leaving the lake through the outlet than entering from the inflows.

Si was highest in the west stream and seepage sites and showed depletion in the midbasin site (Table 3). Fe and Mn were highest in the west stream and littoral zone sites and showed depletion in the midbasin site but not to levels that were likely to limit the growth of algae. Mn concentrations were below detection (0.05 mg/l) in the north inlet and may have limited the growth of algae. Ca, Na and electrical conductivity were high in the seepage area and nearby west littoral zone.

Lake Cochrane P concentrations showed a reverse pattern from that in Oak with high concentrations measured in the inflows and low concentrations measured midbasin (Table 3). TKN was high in both midbasin and the Oliver inflow whereas nitrate+nitrite-N was highest in the west inflow. Because of the higher flow rates in the Oliver inlet, both N and P loading into Cochrane was highest in that inflow (Table 4). Also, the littoral zone downstream from the sediment outlet removes N and P from the water before it enters the lake (Haertel *et al* 1995). There is no littoral zone at the opening of the culvert that dumps Oliver water into Cochrane; nutrient loading shown in Table 4 is the nutrient loading entering the lake. In Cochrane, much more P and N were entering the lake than leaving by the outlet. Cochrane appears to be retaining N and P while Oak is exporting both nutrients downstream.

Concentrations of Si, Fe, Mn and Ca were highest in the west inlet and depleted downstream (Table 3). Conversely, both Na and electrical conductivity levels were highest in the midbasin and outlet sites, reflecting natural concentration processes when the lake had no outlet. Midbasin conductivity levels decreased from 2556 *u*S June 11 to 1805 *u*S August 26, 1998, possibly as a result of flushing Lake Cochrane with water from Lake Oliver.

Phytoplankton

In Oak Lake, coccoid bluegreens, N-fixing filamentous bluegreens, centric diatoms, green algae, and unidentified small flagellates (probably mostly chrysophytes), showed increased concentrations at the midbasin station relative to the inflows (Table 5). Intermediate concentrations of several greens and N-fixing bluegreens were found at the west littoral zone station, probably as a result of mixing with midlake water. Conversely, pennate diatoms, and cryptophyte and euglenophyte flagellates were most abundant at the littoral zone station and low or intermediate at the midbasin station.

Algal taxa not shown in Table 5 included the bluegreens *Calothrix* sp. (most abundant at the midlake station) and *Nodularia harveyensis*, *Lyngbya contorta* and *L. versicolor* (not different between stations); and the greens *Staurastrum gracile* (abundant midlake), *Chlamydomonas* sp. (abundant in the seepage inflow), and *Oocystis* sp. (not different between stations). *Pediastrum* spp. included *P. duplex* + *P. boryanum*. *Nitzschia/Synedra* was probably mostly *N. acicularis*.

In Lake Cochrane, N-fixing bluegreens, green algae, pennate diatoms and filamentous bluegreens were most abundant in water flowing out of the sediment dam. Dinoflagellates and *Botryococcus* were most abundant at the midbasin station. Coccoid bluegreens and chrysophyte flagellates were most abundant in the outflow. (Table 6).

Algal taxa not shown in Table 6 and not differing between stations included the N-fixing bluegreens *A. holsatica* and *Calothrix* sp., the centric diatoms *S. niagarae*, *Chaetoceras elmoreii* and *M. varians*, the green algae, *Monoraphidium* sp. and *Oocystis* sp. and the dinoflagellate *Glenodinium* sp. *Lyngbya* spp. included *L. contorta* and *L. versicolor*. *Nitzschia/Synedra* in Lake Cochrane was probably mostly *N. holsatica*. *Pediastrum* spp. included *P. duplex* + *P. boryanum*. *Scenedesmus* spp. included *S. quadridans* and *S. dimorpha*)

DISCUSSION

Oak Lake and Lake Cochrane process nutrients differently. Cochrane is not experiencing the same midbasin TP concentration as Oak. Cochrane is too deep for wind resuspension of P-rich sediments whereas Oak is not (Haertel 1976). In addition, more abundant algae in Oak raise the pH through photosynthesis. Raised pH increases the solubility of Fe-bound P (Anderson 1975), increasing the probability that suspended sediments will desorb P and stimulate even greater algal growth. This, further raises pH and accelerates the process. Respiration of the very large algal biomass may also lower oxygen levels at the sediment water interface, encouraging P-release (Hosper 1980, 1997). Abundant N-fixing algae in midbasin (table 5) are stimulated by the high P levels.

Once this process has begun, it becomes self-perpetuating; it requires lower nutrient loading to trigger the change back to a less eutrophic stage than is required to trigger the change to a hypertrophic stage (Hosper 1997). Oak has reached this self-perpetuating stage as documented by increased levels of TP, TKN, N-fixing bluegreens and many other algae midbasin. Cochrane has not yet reached this stage, however, if present rates of P loading continue, it may do so.

Vollenwieder (1976) developed an equation for calculating the critical load of P that is likely to trigger the change to a more eutrophic state.

$L_c = E_c \times q_s (1 + (md/q_s)^{0.5})$

Where:

E_c – excessive loading concentration (20 ug/L as per Dillon 1975)

q_s - hydraulic load (m/yr) = md/Tw

Tw - hydraulic residence time (yr) = Lake Volume (m^3)/Annual Inflow (m^3/yr)

md - mean depth (m)

For Lake Cochrane the critical rate of P loading for 1997 flows measured thus becomes 38.8 mg/m^2/yr. Using our 1997 loading rate averages (Table 4), Lake Cochrane is receiving 28.3 mg/m^2/yr from Lake Oliver and 2.0 mg/m^2/yr from the sediment control dam, for a total loading of 30.3 mg/m^2/yr, 0.8 times the critical rate. Non-point source loading (shoreline erosion, fertilizer use etc.) may further contribute to actual loadings, pushing the lake over the critical rate. Groundwater inflows and outflows are also not considered in the above calculation. However, groundwater is more likely to transport N than P.

Applying Vollenwieder's (1976) formula to our 1997 data, the critical rate for Oak Lake is 15.7 mg/m^2/yr and the actual loading rate estimated is 22.0 mg/m^2/yr, 1.4 times the critical rate. Using the longer term stream discharge measurements available for Oak Lake, inflow and outflow rates become about tenfold greater (Table 2). Recalculating the critical rate for Oak using the higher average flows measured during the entire 1996-1998 time period, the critical rate for Oak becomes 72.4 mg/m^2/yr. If the P concentrations measured in the inlets in 1996-1998 were the same as those measured in 1997, then the actual loading of P for Oak lake for the 1996-1998 period would become 236.9 $mg/m^2/yr$, or 3.3 times the critical rate. Thus our estimate of the ratio between the loading rates and the critical rates measured for both Oak and Cochrane during 1997 may be underestimates. During periods of higher inflows, Cochrane may also be exceeding the critical rate. In addition, concentrations of inflowing nutrients may be higher in wetter years. Average total P concentrations of 161 ug/l were measured in the west inlet to Lake Cochrane in 1993 (Haertel *et al* 1995), slightly higher than the 154 ug/l measured in this study.

Because of high midlake concentrations of nutrients, Oak lake exported 473.2 g/d more P to downstream water bodies than the lake received in 1997 (Table 2). Nutrient release from wind-suspended midlake sediments was probably the source of the additional P. Using the higher average flows measured in the 1996-1998 period, and assuming 1997 nutrient concentrations, the estimate of P export rises to 8079.7 g/d. Allowing the outlet to flow naturally thus removes nutrients from Oak Lake.

The situation is reversed in Lake Cochrane. Despite P export through the artificial outlet, Cochrane retained 12.7 g/d of the P coming in the inlets (Table 4). Much of this excess P is probably incorporated into organic material. Increased midbasin concentrations of *Botryococcus* and dinoflagellate plankton support this hypothesis. Since most of this P is coming in from an artificial inflow (Lake Oliver, Table 4) and since the flow data in this paper are based on only three dates of measurement, more nutrient loading data should be collected from Lake Cochrane to properly evaluate the eutrophication risk of the P loading from the Oliver diversion.

Hosper (1997) suggests that nutrient levels need to be much lower to reverse the eutrophication process than to initiate it. Because the algal bloom is self-sustaining in Oak and abundant nutrients are likely to exist in the sediments, improvement in water quality may only be possible through dredging. However, the present high water quality in Lake Cochrane could be more inexpensively preserved by limiting nutrient inputs.

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Table 1. Mean station values of physical and chemical parameters measured in Oak Lake, 1997. Means followed by the same letter are not different ($p > 0.05$).

Parameter	Unit	North Inlet	West Shore			Mid Basin
			Stream	Seepage	Littoral[1]	
Temperature	^{0}C	20ab	18bc	17bc	16c	0.38
Turbidity	ntu	6.1b	4.0b	6.1b	13.1b	114.4a
TP	_g/l	78bc	139b	33bc	126b	277a
NO_3	_g/l	13a	21a	27a	18a	19a
TKN	_g/l	783b	490b	825b	806b	2502a
Si	mg/l	10bc	14ab	16a	9cd	5d
Fe	_g/l	63b	338a	164b	510a	65b
Mn	_g/l	0d	483a	333b	475a	143c
Ca	mg/l	244a	310a	416a	646a	298a
Na	mg/l	4.8b	5.0b	6.5a	6.0a	6.0a
Conductivity	_S/cm	392d	526bc	692a	646ab	472cd
pH	SU	8.2ab	7.7c	7.7bc	7.4c	8.5a

[1]Sampled 17-Jun-98 only.

Table 2. Mean flow rates and phosphorus and nitrogen loading rates estimated from Oak Lake using 1997 measurements and Oak Lake monitoring data.

Source	Flow (l/s)	TN Load (g/d)	TP Load (g/d)
	Based Upon 1997 Flow Measurements[1]		
North Inlet	10.40	715.3	68.3
West Inlet	2.13	94.0	25.5
Seepage	0.92	67.7	2.6
Outlet	23.80	5184.0	569.6
Inlets-Outlet	-10.35	-4307.0	-473.2
	Based Upon 1996-1998 Flow Measurements[2]		
North Inlet	190.00	13067.1	128.0
West Inlet	28.00	1236.2	336.3
Seepage[3]	0.92	67.7	2.6
South Inlet	61.00	3444.2	571.8
Outlet	381.00	82987.3	9118.4
Inlets-Outlet	-101.08	-65172.1	-8079.7

[1]Average stream flows and loadings of nitrogen and phosphorus based upon measurements taken June and July 1997 (excluding the South Inlet).

[2]Average stream flows and loadings of nitrogen and phosphorus based upon stream flows taken during the ice free season (1996-1998) and including the South Inlet (Troelstrup, unpublished data). Nitrogen and phosphorus concentrations assumed from measured data.

[3]Assumed from 1997 measurements, not measured 1996 to 1998.

Table 3. Mean station values of physical and chemical parameters measured in Lake Cochrane 1997. Means followed by the same letter are not different ($p > 0.05$ except where specified).

Parameter	Unit	West Inlet	Oliver Inlet	Mid Basin	Outlet[1]
Temperature	°C	22a	25a	24a	22a
Turbidity	ntu	3.0ab	1.4b	3.9a	2.9ab
TP[2]	_g/l	154a	56b	24c	24c
NO_3	_g/l	82a	36b	74a	111a
TKN	_g/l	793	930	968	780
Si	mg/l	11a	4c	8b	8b
Fe	_g/l	410a	33b	50ab	45b
Mn	_g/l	218a	188ab	152ab	80b
Ca	mg/l	128a	81b	88b	91b
Na	mg/l	10c	37b	54a	55a
Conductivity	_S/cm	1367b	1486b	2119a	2500a
pH	SU	8.3a	8.6a	8.6a	na

[1]Sampled 11-Jun-97 only.
[2] $p > 0.07$
na = not available

Table 4. Mean flow rates and phosphorus and nitrogen loading rates measured in Lake Cochrane, 1997.

Source	Flow (l/s)	TN Load (g/d)	TP Load (g/d)
West Inlet	0.62	8.2	43.7
Oliver Inlet	24.03	116.3	2005.6
Outlet	11.94	24.8	919.2
Inlets-Outlet	21.47	99.7	1130.1

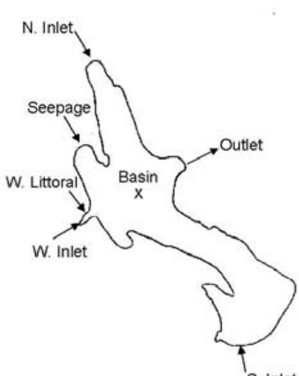

Figure 1. Sampling locations within the Oak Lake basin, Brookings County, South Dakota during 1997.

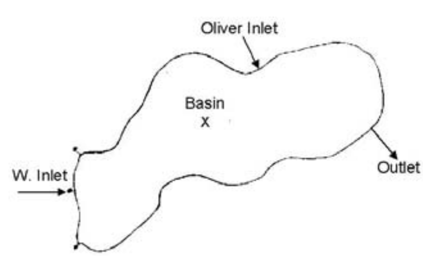

Figure 2. Sampling locations within Lake Cochrane, Deuel County, South Dakota during 1997.

Table 5. Mean station concentrations of major algal taxa measured in Oak Lake 1997. Means followed by the same letter are not different ($p > 0.05$ unless otherwise specified). Number shown times unit multiplier = cells/ml.

Taxon	Unit Mult.	North Inlet	West Shore			Mid Basin
			Stream	Seep	Littoral[1]	
CoccoidBluegreens						
Total	1000	182b	356b	313b	572b	1650a
Anacystis incerta	1000	173b	350b	309b	564b	1424a
A. cyanea	100	4b	5b	1b	12b	1337a
Coccochloris peniocystis	100	5b	59b	52b	76b	886a
N-FixingBluegreens						
Total	1	157b	542b	1561b	2949ab	8484a
Anabaena spp.	1	0b	0b	0b	719ab	4532a
Aphanizomenon holsatica[2]	1	0b	0b	0b	1985a	2110a
Cylindrospermum musicola	1	0b	20b	886ab	245ab	1528a
Centric Diatoms						
Total	1	100b	86b	83b	276b	3729a
Cyclotella glomerata[2]	1	6b	86b	83b	147ab	179a
Stephanodiscus niagarae	1	76b	0b	0b	97b	2175a
Aulacoseira crenulata	1	0b	0b	0b	32ab	303a
Melosira varians	1	0b	0b	0b	0b	280a
Pennate Diatoms:						
Total	1	57c	111bc	205ab	308a	90bc
Nitzschia/Synedra spp.	1	21b	63ab	118ab	135a	54ab
Phaeodactylum tricornutum	1	0b	8ab	6ab	32a	0b
Greens:						
Total	1	550bc	91c	184bc	1377ab	1913a
Sphaerocystis schroeteri	1	0b	0b	0b	58ab	157a
Pediastrum spp.	1	244b	35b	0b	437ab	1153a
Scenedesmus quadridans	1	13b	13b	75ab	170a	107ab
Monoraphidium sp.	1	3b	0b	26b	7b	83a
Crucigenia quadrata	1	52b	22b	0b	231a	26b
Closterium gracile	1	0b	0b	0b	225a	162a
Chrysophytes:						
Total	100	48b	90ab	80ab	83ab	177a
Cryptophytes:						
Total	1	40c	573b	43c	3316a	139c
Euglenophytes:	1	10ab	15ab	4b	45a	13ab

[1] Sampled 17-Jun-97 only.
[2] $p > 0.10$

Table 6. Mean station concentrations of algal taxa measured in Lake Cochrane , 1997. Means followed by the same letter are not different ($p > 0.05$ unless otherwise specified). Number shown times unit multiplier = cells/ml.

Taxon	**Units**	**West Inlet**	**Oliver Inlet**	**Mid Basin**	**Outlet**[1]
CoccoidBluegreens					
Total	1000	163b	241b	286b	684a
Anacystis incerta	1000	153b	229b	225b	533a
Coccochlorispeniocystis	1000	8c	12c	57b	142a
Gloeocapsa sp.	100	1b	1b	3b	101a
FilamentousBluegreens					
Lyngbya spp.	100	187a	11b	23b	65ab
N-FixingBluegreens					
Total	1	1558a	463a	645a	65a
Nodularia harveyensis	1	1475a	408a	528a	65a
Centric Diatoms					
Total	1	23b	37b	158b	1015a
Cyclotellaglomerata[2]	1	7b	20b	157b	925a
Pennate Diatoms:					
Total	1	1825a	54b	55b	245ab
Synedra nitzschia	1	727a	9b	14b	39ab
Phaeodactylum tricornutum	1	1018a	11a	30a	167a
Greens:					
Total	1	4977a	103b	315ab	187ab
Sphaerocystis schroeteri[2]	1	2092a	0b	140b	0b
Scenedesmus spp.[2]	1	275a	27b	0b	0b
Crucigenia quadrata	1	274a	23b	9b	0b
Chlamydomonas sp.	1	2257a	36b	14b	32b
Botryococcus	1	111b	351ab	4673a	412ab
Dinoflagellates:					
Total	1	14b	12b	95a	52ab
Peridinium sp.	1	11ab	10b	88a	52ab
Chrysophytes:					
Total	100	102b	126ab	97b	200a
Dinobryon sertularia	100	36b	6b	438b	1395a
Cryptophytes:					
Total	100	508a	134a	58a	103a

[1] Sampled 11-Jun-97 only.

[2] $p > 0.10$

Figure 1. Sampling locations within the Oak Lake basin, Brookings County, South Dakota during 1997.